Some reflections on methodological aspects of recent climate change damage cost studies[1]

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Introduction

Socially efficient response strategies to the climate change problem require careful considerations of the costs and benefits of mitigation and adaptation measures. The policy challenge is twofold. First it is to minimize the total costs of mitigation, adaptation and residual climate change damage, and second it is to distribute the associated burdens and gains in an equitable manner, both within and between generations. The benefits and costs of mitigation and adaptation measures have to be measured against some baseline, a hypothetical future 'no policy' scenario without mitigation and limited (?) adaptation.[2] Recently, the term 'cost of inaction' has gained popularity in this context, although the term is slightly ambiguous.[3] A distinction can be made between assessments of total damage (and adaptation) costs one the one hand, and marginal damage (and adaptation) costs on the other. Marginal climate change damage (and adaptation) costs are sometimes referred to as the Social Costs of Carbon (SCC).

Assessing the total and/or marginal damage costs of environmental change is often difficult and it is certainly difficult in the case of climate change. A major obstacle is the uncertainty on the physical impacts of climate change, especially related to extreme events and so-called 'climate surprises'. The subsequent transposition of physical impacts into monetary terms is also a delicate step, given that climate change impacts involve both market and non-market goods and services, covering health, environmental and social values, and that impacts may be distant in time and space.

The complexity of climate change cost assessment thus involves several crucial dimensions, including non-market evaluation, risk and uncertainty, baseline definition, equity and discounting, further elaborated in this paper in the course of the overview of the literature and of the overview and evaluation of the key methodological issues.

Overview of recent research projects

The obvious importance of the subject of climate change impacts has elicited a large volume of research on this issue. The overwhelming majority of this research is natural science-based, however. Research on the social and economic consequences of changes in climate, has been far more limited. Within the limited number of economic studies, most studies have either addressed a limited number of possible impacts, a limited geographical area, or both. Studies that have attempted to assess total and/or marginal global damage costs are relatively rare.[4] The number of researchers that carry out such studies, on both sides of the Atlantic, is also small.[5]

Although the volume of work is relatively small, it provides a good basis for further work. In the next section we reflect on some methodological aspects of the studies in the hope that some of the issues raised could be addressed by future studies.

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[2] The type and rate of adaptation in the 'no policy' scenario is problematic, as we will discuss later.

[3] See the interesting discussion by Johnstone, 2005.

[4] In 2005, Richard Toll counted a total of 28 studies globally between 1991 and 2003, of which 18 could be cassified as 'new' impact studies (the others borrowed impact estimates from other studies) . Of these 18 new impact studies 10 had been peer-reviewed (Tol, 2005). Recent (post-2000) studies include Bosello at al., 2004a,b; Bosello, 2005; Darwin and Tol, 2001; Li et al., 2004; Newell and Pizer, 2004; Nordhaus and Boyer, 2000; Rive et al., 2005, Tol, 2005; Tol and Dowlatabadi, 2001. See Table 1.

[5] From the 28 studies reported in Tol (2005) (see footnote 4), four of their authors were involved in more than one study, and one author was even involved in six studies (Nordhaus).

Methodological issues

We reflect on methodological issues concerning the underlying climate and socio-economic, the valuation and estimation approaches used, the assumptions on adaptation, the criteria adopted for temporal and spatial aggregation, the inclusion of uncertainty, irreversibility and the risk of catastrophic events, and the degree of completeness, with regard to the coverage of climate change effects, impacts and adaptation.

Scenarios

A scenario is a set of assumptions on future conditions that is coherent, internally consistent, and plausible. The IPCC makes a distinction between climate scenarios on the one hand, and non-climate scenarios on the other hand. Climate scenarios are usually derived from modeling experiments with Global Circulation Models (GCM). An important distinction can be made between models that compare two equilibrium states of the climate (e.g., a doubling of atmospheric CO_2 concentration or its radiative equivalent), or models that dynamically track transient changes in climate variables (using so-called coupled Atmosphere-Ocean Global Circulation Models: AOGCM). Another important issue for damage assessment is the spatial aggregation of climate models and scenarios. A simple mean global change in temperature may hide important regional variations. A final important distinction is inclusion in the climate scenarios of extreme weather events (hurricanes, tornadoes, storm surges, droughts, floods), and low-probability, high-impact events (or 'climate surprises'), such as a disruption of the thermohaline circulation in the Atlantic Ocean, or the collapse of the West Antarctic ice sheet. These latter types of scenarios have a much higher uncertainty than the scenarios for "average" climate change. Non-climate scenarios include socioeconomic scenarios, land-use and land-cover scenarios, environmental scenarios and sea level rise scenarios. These non-climate scenarios are important as they determine the vulnerability of social and economic systems to climate change over time.[6] They also determine the development of global greenhouse gas emissions leading to a range of emissions scenarios used in GCMs. Many pioneer valuation studies estimated the damage cost of climate change by imposing certain climate change variables (e.g., mean temperature, sea level rise, at a certain point in time) on the present population and economy. In more advanced studies that make use of non-climate scenarios, a distinction can be made between studies that use exogenous scenarios and studies that employ an Integrated Assessment Model (IAM) to generate scenario values.

Valuation approach

For the monetary valuation of climate change effects, various techniques exist. Some values can be directly based on market values. Other values can be indirectly valued on the basis of market prices for surrogate products or services. The challenge in climate change impact studies is to find future market prices that are consistent with the underlying socioeconomic scenario. For some effects, no market values exist. Notable effects are effects on human health and effects on non-commercial ecosystems. The techniques for the valuation of these non-market effects are generally classified into methods that are derived from 'stated preferences' and values that are based on 'revealed preferences'. All current studies of the economic impact of climate change use a mix of valuation methods, but there are no studies comparing the effect of alternative methods on the impact estimates. Because it is practically impossible to estimate each exposure-response relationship or value at the respective place of a climate change impact, data from previous studies focusing on a different region are inevitable. Furthermore, most

[6] Adams et al. (1999) show in an agricultural example how alternative assumptions on socio-economic developments may even change the sign of climate change impacts: from negative (costs) to positive (benefits).

climate change impacts will take place in the future, for which by definition a range of possible outcomes will be available or no information at all. Therefore it is important to know when data from other studies can be used and under what conditions, and how to extrapolate values from today to tomorrow.

Estimation approach

Economic impacts of climate change can be divided into direct impacts and indirect impacts. Direct impacts concern the direct effects on climate change on production or consumption. Indirect impacts concern the indirect effects of changes in production or consumption on the rest of the economy through their effects on relative prices, including factor prices (income). Most studies to date have estimated direct costs under the assumption that indirect effects through changes in goods and factor prices would be negligible. A few studies have used a partial equilibrium approach, including the induced price change of the market in question, but ignoring the effects on other markets. With a few notable exceptions, mainly related to climate change impacts on agriculture and forestry, general equilibrium effects have only recently received attention. A number of recent studies have examined the economy-wide implications of sea level rise, extreme events, climate change impacts on tourism, and on health. While it is perhaps too early to draw firm conclusions from this body of research, the studies suggest that the indirect effects of climate change impacts can both enlarge and diminish the direct economic impacts of climate change. The distribution of gains and losses is another difference between direct costs and general equilibrium effects. Whereas direct costs are limited to those directly affected, markets would spread the impact to their suppliers, clients, and competitors as to financial markets.

Adaptation

Adaptation is complex and hard to capture adequately in an impact assessment. Adaptation to climate change is also very much dependent upon the way in which impacts appear: by gradual changes or by catastrophic events. While adaptation to gradual changes is relatively easy and may not cost much, which is especially true in less vulnerable regions, adaptation to low-probability catastrophic events may be very costly and anticipatory adaptation may even be impossible. Given this complexity, adaptation is not always handled in the same way across studies: different adaptation goals are assumed. For example, in some studies the (implicit) goal of adaptation is to maintain current cropping patterns, others want to maintain current farmers' income, or adjust existing practices in the most efficient manner. Different adaptation goals lead to different adaptation costs and to different residual impacts. Various approaches are used to model adaptation (e.g., spatial analogies, micro-economic optimisation). Impact studies mostly only take autonomous adaptation into account: adaptations that occur without explicit policy interventions by governments. But governments are already embarking on adaptation policies, and are starting such policies well before critical climate change occurs. Most impact studies lump together adaptation costs and residual impacts, and apart for a few recent attempts, they hardly address the trade-off between adaptation and mitigation.

Temporal and spatial aggregation

In order to compare economic effects at different times, these effects are discounted to a common base year. This is particularly important in the economic analysis of climate change, because of the very long time frame in which effects occur. The choice of the appropriate discount *rate*, however, has been a source of controversy and heated debate, both in academic and policy circles. Recently, there seems to be emerging some consensus that the discount rate should not be constant over time, but should decline in the long run. Because of its large impact on estimates of climate change damage, the

discussion on the proper rate of discount remains one of the central methodological issues.[7]

Just as the effects of climate change occur at different times, they also occur at different places. It is now commonly understood that the bulk of climate change damage will be felt in developing countries. There are several reasons for this. Many of the largest changes are projected to occur in developing countries. Their economies rely more on climate-sensitive activities, many operate close to environmental and climatic tolerance levels, and their ability to adapt may be limited because of technical, economic and institutional limitations. However, the monetary value of public goods (including life and health) affected by climate change may vary across countries, which raises questions regarding the marginal utility of income, the aggregation of utilities across individuals, and, indeed, the ethical foundations of cost-benefit analysis. One approach that is often taken by climate impact studies is to give different weights to climate change impacts in different countries or regions on the basis of their respective level of development ("equity weighting"). This seems to be a rather *ad hoc* approach that is in need of further theoretical and empirical elaboration.

Uncertainty and irreversibility

Climate change is plagued by uncertainty. Partly, this is because our understanding of climate change and its impacts is incomplete. For the larger part, however, this is because climate change will take place in the future, driven by future emissions, and impacting a future world. Future research and observations may reduce the uncertainty, although surprises may increase the uncertainty just as well, but uncertainty will never disappear. Learning and irreversibility play a crucial role in how to deal with uncertainty. Events that may or may not occur in some distant future, but whose consequences can be alleviated once it becomes clear if they would occur, should not worry us too much. On the other hand, if an effect is irreversible (e.g., species extinction), we may want to prevent it regardless of how uncertain it is and regardless of what future research will show (according to the "precautionary principle"). Another crucial part of dealing with uncertainty is risk aversion. Essentially, this determines how much weight we place on negative surprises. A risk neutral decision maker would cancel negative surprises against positive ones, but a risk averse decision maker would not. Recent work has shown that the marginal damage costs of carbon dioxide are indeed very sensitive to the assumed degree of risk aversion. Indeed, although uncertainty and risk are often emphasized – often in a casual way – only few studies seek to quantify its implications.

Completeness

Climate change is a multifaceted problem that can have a wide variety of impacts that can give rise to a wide variety of responses. Monetary valuation studies of climate change damage have included various incomplete samples of potential climate change effects, impacts and adaptive responses in their analysis, but none, as yet, included them all. Improving the degree of completeness remains a challenge in this field of research.

Assessment of recent climate change damage studies

Table 1 shows schematically how recent (post-2000) studies have dealt with some of the methodological issues that were discussed in this paper. Table 1 shows that recent studies have taken alternative approaches with respect to these issues. It is shown that some studies use dynamic economy and climate scenarios, but that it is not yet commonplace. The valuation method for non-market goods is predominantly a rough version of benefit

[7] For a recent discussion and an illustration of the effect of different discounting formulae on climate change damage estimates, see Guo et al. (2006).

transfer and there is little attention for the complexities of this method. Adaptation costs are rarely disentangled from residual damage. Equity concerns are not taken into account or only in a slightly ad hoc manner (equity weighting). Uncertainty and risk are dealt with by sensitivity analysis, but not many studies use (fully) stochastic models. Studies deal with one or a limited number of aspects of climate change, but never with all of them.

Conclusions

There is a clear need for more original work on the damage cost of climate change. As new scientific evidence on physical climate change impacts becomes available, and as climate change will start affecting our present-day economies, the quality of the damage estimates will undoubtedly improve and the uncertainty of the estimates will diminish. As another potential source of improvement, this paper suggested a number of methodological issues that could and should be addressed by future research.
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Table 1 – A classification of the most recent studies (post year 2000) based on key methodological issues

Post-2000 Selected studies	Dynamic scenario	Valuation approach		Estimation Approach		Adaptation costs			Temporal aggregation		Spatial aggregation		Uncertainty and risk		Completeness	
		WTP/ WTA	Benefit transfer	Direct impacts	Indirect impacts	Disentangled from residual impacts	Lumped together with residual damage	Trade-off with mitigation	Constant discount rate	Declining Discount rate	With equity weighting	Without	Sensitivity analysis	Statistical uncertainty	Source of impact	Impacted sector
Bosello et al., 2004a,b			X	X	X		X					X	X		Sea-level rise/ extreme events/ temperature increase	Tourism/ Health
Bosello, 2005	X			X	X	X	X	X				X	X		Temperature increase	
Darwin and Tol, 2001			X	X	X	X	X		X			X	X		Sea-level rise	Land & capital lost
Li et al, 2004		X											X			
Newell and Pizer, 2004							X		X	X		X	X	X	CO2 emissions scenarios	
Nordhaus and Boyer, 2000	X			X	X		X			X		X	X		Temperature increase	
Rive et al, 2005			X	X	X		X					X			Change in temperature & precipitation	Forestry
Tol, 2005							X		X	X	X	X		X		
Tol and Dowlatabadi, 2001	X		X	X	X	X		X				X	X		Temperature increase	Health (vector-born diseases)